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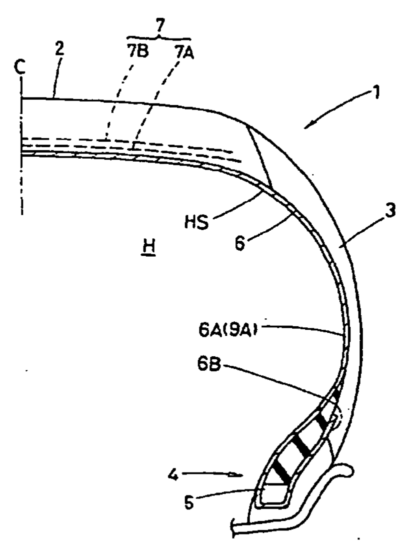
(54) Pneumatic tyre

(57) A pneumatic tyre comprising a carcass (6) comprising a ply (9) of cords (10) defining the innermost reinforcing cord layer extending between bead portions (4), and an airtight layer disposed inside the cords (10) of the carcass ply along the inner surface of the tyre, covering the substantially entire inner surface of the tyre, wherein the airtight layer is made of air-impermeable rubber including at least 10 weight % of halogenated butyl rubber and/or halogenated isobutylene-paramethyl styrene copolymer in its rubber base, and a thickness (T2) of the airtight layer measured from the inner surface of the tyre to the cords of the carcass ply is in a range of from 0.2 to 0.7 mm.

Fig.1



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Description

[0001] The present invention relates to a pneumatic tyre having an improved airtight layer being capable of reducing the tyre weight.

[0002] Conventionally, a pneumatic tyre is provided inside the carcass with a so called inner liner to retain the tyre inflation pressure.

[0003] In recent years, pneumatic tyres are strongly required to have reduced weight from environmental aspects. Therefore, various proposals have been made. For example, laid-open Japanese patent applications JP-A-H06-156007 and JP-A-H08-113007 disclose a pneumatic tyre wherein, a cord ply rubberised with an air-impermeable rubber compound is used in the carcass, and the conventional inner liner is eliminated. The tyre weight is therefore, reduced accordingly.

[0004] In practice, however, it is very difficult to uniformly reduce the thickness of rubber inside the carcass as claimed in this invention because during vulcanising the tyre, the tyre inner surface is pressed by an inflated bladder and the bladder rubs the inside of the carcass ply. If the bladder touches the carcass cords, the carcass cords are exposed, and not only the airtightness but also the resistance to humidity decreases thus deteriorating the durability.

[0005] Therefore, a principal object of the present invention is to provide a pneumatic tyre in which, in order to reduce the tyre weight, the rubber thickness of an airtight layer disposed along the inner surface of the tyre is minimised uniformly without defects such as breakage.

[0006] Another object of the present invention is to provide an improved airtight layer having minimum thickness without sacrificing the airproofing power.

[0007] According to the present invention, a pneumatic tyre comprises a tread portion, a pair of sidewall portions, a pair of bead portions, a carcass comprising a ply of cords defining the innermost reinforcing cord layer extending between the bead portions, and an airtight layer disposed along the inner surface of the tyre covering the substantially entire inner surface of the tyre, the airtight layer being made of air-impermeable rubber including at least 10 weight % of halogenated butyl rubber and/or halogenated isobutylene-paramethyl styrene copolymer in its rubber base, and the thickness of the airtight layer measured from the inner surface of the tyre to the cords of the carcass ply being in a range of from 0.2 to 0.7 mm.

[0008] Embodiments of the present invention will now be described in detail in conjunction with the accompanying drawings, in which:

Fig.1 is a schematic cross sectional view of a pneumatic tyre according to the present invention;
Figs.2A and 2B are enlarged schematic cross sectional views each showing an example of the arrangement of the airtight layer and the innermost carcass cords;
Fig.3 is a diagram showing a raw carcass ply material transformed into a toroidal shape resembling its final shape in the vulcanised tyre;
Fig.4 is a diagram for explaining a method of making a raw carcass ply material;
Fig.5A is a diagram showing an example of the raw carcass ply material in a spread state;
Fig.5B is a diagram showing the same wound into a loop;
Fig.5C is an enlarged schematic cross sectional view showing a splice joint thereof;
Fig.6A is a diagram showing another example of the raw carcass ply material in a spread state;
Fig.6B is a diagram showing the same is wound into a loop;
Figs.6C and 6D are enlarged schematic cross sectional views showing splice joints thereof; and
Figs.7 and 8 are enlarged schematic cross sectional views showing alternative butt joint and structures therefor.

[0009] Note) In the enlarged schematic cross sectional views, the rubber thicknesses, especially those of the airtight layers, are exaggerated.

[0010] In the drawings, a pneumatic tyre 1 according to the present invention comprises a tread portion 2, a pair of sidewall portions 3, and a pair of bead portions 4 each with a bead core 5 therein. The tyre 1 is reinforced by a carcass 6 extending between the bead portions 3 through the tread portion 2 and has sidewall portions 3 and a tread reinforcing belt disposed radially outside the crown portion of the carcass 6 in the tread portion 2.

[0011] The embodiment schematically shown in Fig.1 is a passenger car tyre. However, the present invention can be applied to various pneumatic tyres.

[0012] The belt comprises a breaker 7 and optionally a band (not shown).

[0013] The breaker 7 is composed of at least two crossed plies 7A and 7B of high modulus cords laid parallel with each other at an angle of from 10 to 35 degrees with respect to the tyre equator.

[0014] The band is disposed on the radially outside of the breaker 7 and the cord angle with respect to the tyre equator is almost zero or a small angle of at most 10 degrees.

[0015] The carcass 6, on one hand, comprises a ply 9A of cords 10 provided as the innermost reinforcing cord layer

extending between the bead portions 4 at least.

[0016] The carcass 6, on the other hand, comprises at least one ply 9 of cords 10 arranged at an angle alpha of 75 to 90 degrees with respect to the tyre equator, and extending continuously between the bead portions 4 through the tread portion 2 and sidewall portions 3, and turned up around the bead core 5 in each bead portion from the axially inside to the axially outside so as to form a pair of turned up portions 6B and a main portion 6A therebetween. The carcass 6 may be composed of only the single ply 9. In this case, the ply 9A is defined by the main portion 6A. Further, the carcass 6 may be composed of two plies 9 both of which are turned up from the inside to the outside as explained above. In this case, the ply 9A is defined by the main portion 6A of the inner carcass ply. Furthermore, the carcass 6 may be composed of the above-mentioned ply 9 turned up from the inside to the outside and another ply which is disposed outside the ply 9 and turned up reversely from the outside to the inside or not turned up so as to terminate in the bead portion. In this case, the ply 9A is defined by the main portion 6A of the carcass ply 9.

Airtight layer

[0017] According to the present invention, an airtight layer is disposed along the inner surface HS of the tyre, covering the substantially entire surface HS. Here, as shown in Fig.2A and Fig.2B, the airtight layer is defined by a rubber layer between the tyre inner surface HS and the innermost cords 10, namely, the carcass cords 10 of the ply 9A. The thickness T2 of the airtight layer measured from the tyre inner surface HS to the carcass cords 10 is decreased into a range of from 0.2 to 0.7 mm.

[0018] The airtight layer is made of one or more kinds of air-impermeable rubber compounds, including a topping rubber 12 of the carcass ply 9A.

[0019] In the examples shown in Figs.2A and 2B, the topping rubber 12 of the carcass ply 9A has a double layered structure comprising an inner topping rubber 12i made of an air-impermeable rubber compound 13, and an outer topping rubber 12o made of another kind of diene-base rubber 14 which is not air-impermeable. The boundary K between the inner topping rubber 12i and outer topping rubber 12o is preferably laid outside the innermost points of the carcass cords 10 as shown in Figs.2A and 2B. In these two examples, the boundary K reaches to the centre of the cords.

[0020] The outer topping rubber 12o, however, may be made of the same air-impermeable rubber compound 13 or a similar air-impermeable rubber compound. In case of an air-impermeable rubber compound which is similar to but different from the inner topping rubber 12i, the boundary K may be laid inside the carcass cords 10.

Air-impermeable rubber compound

[0021] The air-impermeable rubber compound 13 which is used as carcass cord topping rubber includes, as its rubber base, 10 to 50 weight % of halogenated butyl rubber and/or halogenated isobutylene-paramethyl styrene copolymer, and 90 to 50 weight % of diene rubber so as to provide low air-permeability and strong adhesion to the cords 10 and another abutting rubber 14.

[0022] Further, the air-impermeable rubber compound 13 includes 45 to 60 parts by weight of carbon black with respect to 100 parts by weight of the rubber base.

[0023] Here, the diene rubber means natural rubber, butadiene rubber, styrenebutadiene rubber, isoprene rubber, chloroprene rubber, acrylonitrile butadiene rubber and the like, which may be used alone or in combination.

[0024] For the halogenated butyl rubber, chlorinated butyl rubber and/or brominated butyl rubber may be used.

[0025] Hereinafter, the halogenated butyl rubber and halogenated isobutylene-paramethyl styrene copolymer are called "low-air-permeability rubber component(s)".

[0026] From a point of view of the adhesiveness, it is preferable that the diene rubber is not less than 65 weight % and the total of the low-air-permeability rubber component(s) is not more than 35 weight %. And the isobutylene content of the halogenated isobutylene-paramethyl styrene copolymer is in a range of from 89 to 97 weight %, more preferably 89 to 95 weight %, still more preferably 89 to 93 weight %.

[0027] The above-mentioned carbon black preferably has

(1) (a) an iodine adsorption number of 80 to 125 mg/g or (b) a specific surface area (nitrogen adsorption method) of 80 to 120 m2/g, and

(2) (c) a dibutyl phthalate adsorption number of 70 to 100 ml/100g or (d) dibutyl phthalate adsorption number (compressed sample) of 70 to 90 ml/100g, namely, (a)+(c) or (a)+(d) or (b)+(c) or (b)+(d).

[0028] Here, the above-mentioned iodine adsorption number, specific surface area (nitrogen adsorption method), dibutyl phthalate adsorption number, and dibutyl phthalate adsorption number (compressed sample) are measured

according to the Japanese Industrial Standard K6217 - "Testing methods of fundamental characteristics of carbon black for rubber industry", Sections 6, 7, 9 and 10, respectively.

[0029] By using carbon black with these parameters limited as above, even if the carbon black content is decreased in the above-mentioned range of from 45 to 60 parts by weight, sufficient reinforcement can be obtained together with flexibility in the vulcanised state. Thus, the crack resistance against bending deformation, tensile strength and the like may be improved.

[0030] Further, in the unvulcanised state of the rubber compound 13, the viscosity (Mooney viscosity) is increased to lessen the flow of rubber during vulcanising. As a result, the above-mentioned rubber thickness T2 measured from the tyre inner surface HS to the carcass cords 10 can be maintained stably in the above-mentioned range of from 0.2 to 0.7 mm.

[0031] If the iodine adsorption number is less than 80 mg/g or the specific surface area is less than 80 m2/g, then it is difficult to maintain the specific rubber thickness T2 because the unvulcanised rubber is provided with an excess liquidity or excess mobility. Further, the tensile strength and breaking strength of the vulcanised rubber tend to decrease.

[0032] If the iodine adsorption number is more than 125 mg/g or the specific surface area is more than 120 m2/g, then the hardness of the vulcanised rubber is liable to increase excessively to deteriorate ride comfort of the tyre.

[0033] If the dibutyl phthalate adsorption number is less than 70 ml/100g or the dibutyl phthalate adsorption number (compressed sample) is less than 70 ml/100g, then the tensile strength is liable to become insufficient.

[0034] If the dibutyl phthalate adsorption number is more than 100 ml/100g or the dibutyl phthalate adsorption number (compressed sample) is more than 90 ml/100g, then the unvulcanised rubber is increased in the viscosity and the processibility becomes worse. Further, the bending fatigue resistance of the vulcanised rubber decreases.

[0035] If the carbon content is increased to compensate for the lack of the tensile strength, then the heat build-up in tyre use unfavourably increases. Thus, this technique can not be adopted.

[0036] Usually, a plasticiser such as phthalic acid derivatives, softener, e.g. mineral oil, aroma oil and the like is used to improve the processibility and plasticity.

[0037] Such plasticiser may be used in this invention, but in this embodiment, in order to improve the adhesiveness of the air-impermeable rubber compound 13, a tackifier is added rather than plasticiser. For such tackifier, coumarone resin, phenol resin, terpene resin, petroleum hydrocarbon resin, rosin derivatives may be used. The content of the tackifier is set in a range of from 1 to 10, preferably 3 to 10, more preferably 3 to 8 parts by weight with respect to 100 parts by weight of the rubber base.

[0038] In the example shown in Fig.2A, the airtight layer is the inner topping rubber 12i only, namely, the above-mentioned air-impermeable rubber compound 13.

Insulation rubber layer

[0039] In the example shown in Fig.2B, the airtight layer is made of the topping rubber 12i (or the above-mentioned air-impermeable rubber compound 13) and a second air-impermeable rubber compound 15 which forms an insulation rubber layer 17.

[0040] When the thickness T2 is decreased to near its lower limit of 0.2 mm, it is difficult to maintain such a small thickness stably without breaking partially. In general, during vulcanising a green tyre in a mould, in order to press the green tyre against the mould, the green tyre is inflated to a high pressure using an inflatable bladder set inside the green tyre. The bladder is very likely to come into contact with the innermost cords 10. As a result, the airtight layer breaks at the contact point. The insulation rubber layer 17 can solve this problem.

[0041] The insulation rubber layer 17 is provided inside the carcass ply topping rubber 12i as the innermost rubber layer which faces the tyre cavity and comes into contact with a bladder during tyre vulcanisation.

[0042] The insulation rubber layer 17 is made of the second air-impermeable rubber compound 15 as mentioned above. This compound 15 has ingredients which are similar to the above-mentioned ingredients of the air-impermeable rubber compound 13 but the content of the "low-air-permeability rubber component(s)" is increased, that is, the content thereof is set in a range of from 60 to 100 weight % and accordingly the remainder or the diene rubber is decreased into a range of 40 to 0 weight % so that the second air-impermeable rubber compound 15 is provided with fluidity, and the air-impermeable rubber compound 13 is provided with less fluidity during vulcanising the tyre.

[0043] Preferably, the ratio TQ1/T2 of a minimum torque TQ1 of the air-impermeable rubber compound 13 to a minimum torque TQ2 of the second air-impermeable rubber compound 15 is set in a range of not less than 1.1, and preferably at most 2.0.

[0044] Here, the minimum torque is obtained from the cure curve obtained under the following conditions according to the Japanese Industrial Standard K6300-"Physical testing methods for unvulcanised rubber", Section 8.4 "Die vulcanisation test-A method". That is, by oscillating a lower die, the torque transmitted from the lower die to an upper die through the specimen is measured. Conditions: Temperature of 170 deg.C; Angularly amplitude of plus/minus 1 degrees; and Oscillation of 100 cycles/minute.

[0045] As to the thickness distribution, the thickness T3 of the air-impermeable rubber compound 13 measured from the innermost points of the cords 10 to the boundary between the topping rubber 12i and the insulation rubber layer 17 is set in a range of from 0.1 to 0.2 mm when the boundary K or the outward extent of the air-impermeable rubber compound 13 is not laid inside an envelope of the centres of the cords. In this case too, the thickness T2 of the airtight layer as the total thickness of these two compounds 13 and 15 is set in the range of from 0.2 to 0.7 mm as mentioned above.
[0046] As a result, the force which the inner topping rubber 12i receives from the inflated bladder during vulcanisation is evened out by the increased fluidity of the second air-impermeable rubber compound 15 and the force is decreased because the insulation rubber layer 17 functions as a lubricant. These effects and a effect by the less fluidity of the air-impermeable rubber compound 13 make the inner topping rubber thickness T3 stable.
[0047] Such a minimum torque difference TQ1-TQ2 may be provided by increasing the carbon content of the air-impermeable rubber compound 13 up to 10 weight % than the second air-impermeable rubber compound 15.
[0048] If the ratio TQ1/TQ2 exceeds 2.0 due to the increased carbon content of the air-impermeable rubber compound 13, it becomes difficult to rubberise the carcass cords.
[0049] In the vulcanised state, on the other hand, it is preferable that the complex elastic modulus E*1 of the air-impermeable rubber compound 13 is not more than 5.5 MPa and the complex elastic modulus E*2 of the second air-impermeable rubber compound 15 is not more than 5.0 MPa.
[0050] Here, the complex elastic modulus is measured under the following conditions: Temperature of 70 deg.C; Frequency of 10 Hz; Initial strain of 10 %; and Dynamic distortion of plus/minus 1%.
[0051] If the complex elastic modulus E*1 is more than 5.5 MPa, then the rigidity is liable to increase excessively to decrease the resistance to bending fatigue. If the complex elastic modulus E*2 is more than 5.0 MPa, then the rigidity is liable to increase excessively to decrease the resistance to cracks.

Method of making the pneumatic tyre

[0052] Next, a method of making the pneumatic tyre will be described. To be brief, the pneumatic tyre is made as follows.
[0053] A raw carcass ply material is wound around a tyre building drum into a cylindrical shape. Two bead cores are set on the raw carcass ply material on the drum. The raw carcass ply material is transformed from the cylindrical shape to a toroidal shape by expanding the tyre building drum while decreasing the distance between the bead cores (bead portions) as shown in Fig.3. Reinforcing cord layers such as the belt and rubber components such as sidewall rubber, bead clinch rubber, tread rubber, etc. are applied at appropriate times. The green tyre build as such is put in a mould, and an inflatable bladder is set inside the tyre. The bladder is inflated during heating of the green tyre.

Method of making the raw carcass ply material

[0054] The above-mentioned raw carcass ply material 16 is made as follows.
[0055] First, as shown in Fig.4, a lengthy cord fabric D is made, wherein carcass cords 10 are laid parallel with each other at a predetermined cord count in the widthwise direction thereof so as to extend along the longitudinal direction of the fabric and the cords 10 are rubberised with topping rubber 12.
[0056] The cord fabric D is cut into pieces D1 according to the width La of the carcass ply material 16 and the carcass cord angle alpha with respect to the tyre equator. To be precise, the inclination of the cutting line with respect to the longitudinal direction is alpha, and the spacing between the cutting lines in the longitudinal direction of the fabric D is equal to La x sin(alpha).
[0057] The cut pieces D1 are spliced by overlapping the side edges De while aligning the cut edges, whereby a lengthy spliced cord fabric F in which carcass cords are embedded in parallel with each other at the angle alpha with respect to the longitudinal direction thereof is formed.
[0058] By cutting the lengthy spliced cord fabric F into a certain length, the raw carcass ply material 16 is formed. (See Fig.5A)
[0059] The raw carcass ply material 16 is wound around the tyre building drum and the ends Fe thereof are spliced to make it cylindrical. (See Fig.5B)
[0060] In the case of Fig.2A where the airtight layer is made of one kind of rubber compound 13, the above-mentioned raw carcass ply material 16 may be used directly as shown in Fig.5A and 5B.
[0061] Fig.5C shows the resultant splice joints (J1) between the side edges De and splice joint (J2) between the ends Fe.
[0062] In the case of Fig.2B where the airtight layer is made up of the topping rubber 12i and the insulation rubber layer 17, the insulation rubber layer 17 is applied to the inside of the lengthy spliced cord fabric F before cut into the raw carcass ply material 16. The raw carcass ply material 16 with the insulation rubber layer 17 shown in Fig.6A is

wound around the tyre building drum and the ends Fe thereof are spliced to make it cylindrical as shown in Fig.6B. Fig.6C shows the resultant splice joints (J1) between the side edges De which are covered with the insulation rubber layer 17. Fig.6D shows the resultant splice joint (J2) between the ends Fe which is not covered.

[0063] Therefore, when viewed from the inside of the loop, only one joint (J2) is seen in Fig.6B although a plurality of joints (J1 and J2) are seen in the case of Fig.5B.

[0064] As explained above, during vulcanising the tyre, the airtight layer comes into contact with the bladder.

[0065] In order to easily release the vulcanised tyre therefrom, conventionally, mould lubricant is sprayed on the inner surface of the green tyre.

[0066] In this invention, if such a mould lubricant or a similar release agent is applied to the inner surface of the green tyre, in order to prevent any penetration of such a chemical which may causes a separation failure and lowering of airtightness, it is better to cover the above-mentioned joints J1 and J2 on the tyre inner surface with a rubber patch 22 as shown in Figs.5C and 6D by an imaginary line.

[0067] The rubber patch 22 is an unvulcanised rubber tape whose thickness T1 is in a range of from 0.1 to 0.5 mm and width W1 is in a range of form 5 to 80 mm, preferably 25 to 50 mm.

[0068] For the rubber patch, a rubber compound which is not air-impermeable may be used, but preferably an air-impermeable rubber compound is used which is the same as or similar to the air-impermeable rubber compound 13 or the second air-impermeable rubber compound 15 which is disposed as the innermost rubber layer and thus comes into contact with the patch.

[0069] The use of the rubber patch 22 is effective in preventing the penetration. In case of Fig.5A, the patches to the joints (J1) may be applied in the state of a lengthy spliced cord fabric F in advance. But, in either case of Fig.5A and Fig.6A, an additional work to apply the patch to the joint (J2) is unavoidable.

[0070] In this embodiment, to save such trouble and time, the rubber patch 22 is not used and also a mould lubricant or release agent is not applied to the tyre inner surface HS.

[0071] It is however necessary to prevent bridging between the tyre inner surface HS and the bladder. Therefore, the following release agent is applied to the surface of the bladder. In this example, a solution of an organic solvent such as gasoline and a combination of amide compound and silicon is used as the release agent. The solution is applied to the surface of the bladder and volatilised so that the surface is covered with a thin film.

[0072] Fig.7 shows an alternative example of Fig.6A. In this example, the side edges De of the cut pieces D1 are butt jointed. In this case, the insulation rubber layer 17 will be function as a base to retain the butted state.

[0073] Fig.8 shows an alternative example of Fig.5A. In this example, the side edges De of the cut pieces D1 are butt jointed. In this case, the above-mentioned rubber patch 22 is preferably utilised so that the cut pieces D1 retain the butted state.

Example of Rubber compounds

[0074] Table 1 and Table 2 show examples of rubber compounds and their characteristics. The definitions of or measuring methods for the characteristics are as follows.

(1) Mooney viscosity:

[0075] Mooney viscosity (ML1+4,130 deg.C) at a temperature of 130 deg.C was measured according to Japanese Industrial Standard K6300 - "Physical testing methods for unvulcanised rubber", Section 6 - "Mooney viscosity test". The measured values are indicated by an index. The larger the index number, the higher the viscosity.

(2) Air permeability:

[0076] Air permeability was measured according to the American Society for Testing Materials D1434-75M test method using a specimen vulcanised under a temperature of 170 deg.C. a pressure of 9.8 MPa and a curing time of 12 minutes. The smaller the value, the lower the air permeability.

(3) Flex crack resistance:

[0077] Flex crack resistance was measured according to the Japanese Industrial Standard K6260 - "Flex cracking test method for vulcanised rubber" except for the stroke of the reciprocal motion for causing bending strain. The length of the crack was measured after undergone bending deformation by 50% of the specified stroke 1,000,000 times and after undergone bending deformation by 70% of the specified stroke 300,000 times. In the table, the reciprocal of the length is indicated by an index. The larger the index number, the higher the flex crack resistance.

(4) Adhesiveness:

(4-1) Adhesion 1 (to cords):

[0078] Two perpendicularly crossing laminated plies of parallel 1670 dtex/2 polyester cords (cord count: 48/5 cm) rubberised with the concerned rubber compound were made and vulcanised under a temperature of 150 deg.C, a pressure of 9.8 MPa, and a curing time of 30 minutes. And a peeling test at a speed of 50 mm/minute was made to obtain an adhesive strength. Under 300 N/25 mm is not acceptable.

(4-2) Adhesion 2 (to Sidewall rubber):

[0079] A sheet of the concerned rubber compound and a typical sidewall rubber compound C1 shown in Table 3 (2 mm thickness, 80 mm width, 150 mm length) attached to each other were vulcanised under a pressure of 2 MPa, a temperature of 150 deg.C, a curing time of 30 min. And a peeling test at a speed of 50 mm/minute was made to obtain an adhesive strength. Under 50 kgf/25 mm is not acceptable.

(4-3) Adhesion 3 (to general topping rubber):

[0080] Using a cord fabric of parallel 1670 dtex/2 polyester cords (cord count: 48/5 cm) whose inside was rubberised with the concerned rubber compound and outside was rubberised with a typical topping rubber compound C2 shown in Table 3, two perpendicularly crossing laminated plies were made and vulcanised under a temperature of 150 deg. C, a pressure of 9.8 MPa, and a curing time of 30 minutes. And a peeling test at a speed of 50 mm/minute was made to obtain an adhesive strength. Under 300 N/25 mm is not acceptable.

Tyre comparison tests

[0081] Table 4 shows results of comparison tests for tyre performance. Using the above-mentioned rubber compounds shown in Tables 1 and 2, pneumatic tyres of size 185/65R14 (wheel rim size 5.5JX14) having the structure shown in Fig.1 were made and tested for air leak and durability.

(A) Air leak test:

[0082] The tyre mounted on its standard wheel rim was inflated to 300 kPa and then the pressure was measured after 90 days. The rate of decrease is indicated by an index. The larger the index number, the better the performance.

(B) Durability test 1:

[0083] Using a tyre test drum, the tyre mounted on its standard wheel rim and inflated to 190 kPa was run for 20,000 km under a tyre load of 5.0 kN at a speed of 80 km/hr. In the table, "ok" means there was no damage after running for the captioned distance. The number means a running distance in percentage of the captioned distance at which cracks or separation occurred.

[0084] Table 5 shows results of further comparison tests for tyre performance. Pneumatic tyres of size 195/65R15 having the structure shown in Fig.1 were made using the rubber compounds shown in Table 6 and tested for air leak and durability.

(A) Air leak test:

[0085] Same as above

(C) Durability test 2:

[0086] Using a tyre test drum, the tyre mounted on its standard wheel rim of size 5.5JX14 and inflated to 190 kPa was run under a tyre load of 6.96 kN at a speed of 70 km/hr until any damage occurred on the tyre outer surface and the running distance was measured. The running distance is indicated by an index. The larger the index number, the better the durability.

Table 1

Rubber compound	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10
Natural rubber	90	70	50	90	70	50	70	70	70	70	100	40	40	60	60	60	60	60	60	60
EXXPRO90-10 (*1)	10	30	50	--	--	--	30	30	30	30										
Butylbromide	--	--	--	10	30	50	--	--	--	--	--	--	60	--	--	--	--	--	--	--
Carbon (Table 3)																				
N219	50	50	50	50	50	50	45	--	--	25	50	50	50	--	--	--	--	--	35	70
N234	--	--	--	--	--	--	--	--	--	--	--	--	--	50	--	--	--	--	--	--
N326	--	--	--	--	--	--	--	50	60	25	--	--	--	--	50	--	--	--	--	--
N330	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	50	--	--	--	--
N550	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	50	60	--	--
Stearic acid	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Tackifier	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Insoluble sulfur	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5
Hydrozincite	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
Age resistor	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Accelerator	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Mooney viscosity	133	140	145	127	135	140	125	129	159	135	100	152	146	133	129	118	105	133	110	189
Air permeability	32	20	13	32	19.8	12.5	20.5	20.1	18.1	20	39.5	9.6	9.7	16.5	16	15.8	15.3	13.5	18	14.4
Flex crack resistance																				
50%	131.1	109.9	65.9	104.9	87.9	52.7	244.8	103.9	59.8	105	38.4	86.9	86.9	29.8	42.9	100	93.4	33.3	179.6	35.9
70%	12.2	9.5	5.7	9.8	7.8	7.8	15.6	9.7	5.6	9.4	1.8	6.6	6.6	5.2	3.2	4.9	5.1	4.6	12.2	3.6
Adhesion																				
1 (N/25 mm)	327.9	320.7	312.4	314.4	310.5	301.5	327.1	304.7	301.5	312.6	335	248.2	244.5	288	233.1	218.7	283.6	224.5	270.8	335.4
2 (kgf/25 mm)	137.4	99.6	57.2	138.7	104	57	101.6	94.6	91.8	76	102.1	33.3	32.9	73.9	46.7	42.2	62.6	43.7	69.2	82.3
3 (N/25 mm)	345.1	336.8	314.5	334	320.5	303.4	343.5	319.9	316.7	317.2	342.1	255.1	252	296.9	240.1	225.2	292.4	251.8	278.9	345.4

*1) halogenated isobutylene-paramethyl styrene copolymer

Table 2

Rubber compound	C1	C2
Natural rubber	40	70
Butadiene rubber	60	--
Styrene butadiene rubber	--	30
Carbon black		
N550	60	--
N330	--	50
Plasticiser		
Aroma oil	2	--
Mineral oil	--	10
Stearic acid	2	2
Hydrozincite	2.5	5
Insoluble sulfur	1.5	4
Accelerator	1	1

Table 3

Carbon black in Tables 1 and 2	N219	N234	N326	N330	N550	N660
Iodine adsorption number (mg/g)	116	119	86	71	45	27
Specific surface area (nitrogen adsorption method)(m2/g)	112	121	83	76	42	31
Dibutyl phthalate adsorption number(ml/100g)	83	120	72	102	117	87
Dibutyl phthalate adsorption number (compressed sample) (ml/100g)	80	78	70	85	84	70

Table 4

Tyre	Ex.1	Ex.2	Ex.3	Ex.4	Ex.5	Ex.6	Ex.7	Ex.8	Ex.9	Ex.10	Ref.1	Ref.2	Ref.3	Ref.4	Ref.5	Ref.6	Ref.7
Topping rubber																	
Inside	A2	A4	A5	A6	A2	A4	A5	A6	A2	A2	C2	B1	B2	B4	B7	B10	B4
Outside	A2	A4	A5	A6	C2	C2	C2	C2	A2	C2	C2	C2	C2	C2	C2	C2	C2
Thickness T2 (mm)	0.45	0.4	0.41	0.49	0.44	0.4	0.41	0.48	0.46	0.45	0.9	0.32	0.48	0.41	0.34	0.56	0.42
Insulation rubber layer	none	none	none	none	none	None	none	none	present	present	none	none	none	none	none	none	present
Tyre weight(index)	95	95	95	96	95	95	95	96	95	95	100	95	95	95	95	96	95
Air leak	105	103	106	108	104	103	105	107	105	104	100	86	112	105	108	110	105
Durability																	
20000 km	ok	ok	ok	ok	ok	Ok	ok	ok	ok	ok	ok	ok	60	ok	ok	ok	ok
40000 km	ok	ok	ok	ok	ok	Ok	ok	ok	ok	ok	ok	ok	-	ok	70	85*	ok
60000 km	ok	ok	ok	ok	ok	Ok	ok	ok	ok	ok	ok	70*	-	68*	-	-	70

*) Tyre inner surface cracked.

Table 5

Tyre	Ex.11	Ex.12	Ex.13	Ex.14	Ex.15	Ref.12	Ref.13	Ref.17	Ref.18	Ref.11	Ref.14	Ref.15	Ref.16
Topping rubber													
Inside	R2'	R2'	R2'	R2'	R2'	R3	R2	R2"	R2'	R1	R2	R2	R2
Outside	R1	R1	R2'	R2'	R1	R1	R1	R1	R1	R1	R1	R1	R1
Thickness T2 (mm)	0.42	0.4	0.41	0.38	0.17	0.35	0.15	0.43	0.4	1.12	0.37	0.42	0.33
Insulation rubber layer	R4	R4	R4	R4	R4	R4	R4	R4	R5	none	none	none	none
TQ1/TQ2	1.21	1.21	1.21	1.21	1.21	1.38	0.98	1.37	1.21	-	-	-	-
E*1 (MPA)	4.8	4.8	4.8	4.8	4.8	-	3.9	5.9	4.8	-	-	-	-
E*2 (MPA)	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	5.6	-	-	-	-
Tyre weight (index)	96	96	95	96	94	95	95	96	96	100	95	95	94
Air leak	82	80	79	76	102	77	104	81	78	100	95	95	89
Durability	108	105	102	104	88	67	80	79	78	100	75	102	74

Table 6

Rubber compound in Table 5	R1	R2	R2'	R3	R4	R5	R2"
Natural rubber	70	70	70	40	30	30	70

Table 6 (continued)

Rubber compound in Table 5	R1	R2	R2'	R3	R4	R5	R2"
Styrene butadiene rubber	30	-	-	-	-	-	-
EXXPRO90-10 (*1)	-	-	-	-	-	-	30
Butylbromide	-	30	30	60	70	70	-
Carbon	45HAF	45HAF	55HAF	55HAF	60GPF	60HAF	65HAF
Stearic acid	2	2	2	2	1	1	2
Tackifier	0	5	5	5	5	5	5
Sulfur	4	3.75	3.75	3.75	1	1	3.75
Accelerator	1	1	1	1	1	1	1
Hydrozincite	5	5	5	5	4	4	5
Plasticiser (oil)	10	0	0	0	5	5	0

*1) Halogenated isobutylene-paramethyl styrene copolymer

Claims

1. A pneumatic tyre comprising a tread portion (2), a pair of sidewall portions (3), a pair of bead portions (4), a carcass (6) comprising a ply (9) of cords (10) defining the innermost reinforcing cord layer extending between the bead portions (4), an airtight layer disposed inside said cords of the carcass ply along the inner surface of the tyre, covering the substantially entire inner surface of the tyre, **characterised in that** the airtight layer is made of air-impermeable rubber including at least 10 weight % of halogenated butyl rubber and/or halogenated isobutylene-paramethyl styrene copolymer in its rubber base, and the thickness (T2) of the airtight layer measured from the inner surface of the tyre to the cords (10) of the carcass ply is in a range of from 0.2 to 0.7 mm.

2. A pneumatic tyre according to claim 1, **characterised in that** the airtight layer is made of one kind of air-impermeable rubber compound comprising 100 parts by weight of rubber base and 45 to 60 parts by weight of carbon black, said rubber base comprising 10 to 50 weight % of halogenated butyl rubber and/or halogenated isobutylene-paramethyl styrene copolymer and 50 to 90 weight % of diene rubber, the carbon black having the following parameters (1) and (2):

   (1) an iodine adsorption number of from 80 to 125 mg/g or a specific surface area (nitrogen adsorption method) of from 80 to 120 m2/g,
   (2) a dibutyl phthalate adsorption number of from 70 to 100 ml/100g or a dibutyl phthalate adsorption number (compressed sample) of 70 to 90 ml/100g.

3. A pneumatic tyre according to claim 1, **characterised in that** the airtight layer is made of a first air-impermeable rubber compound and a second air-impermeable rubber compound; the first air-impermeable rubber compound forms an outer layer (12o) coming into contact with the cords (10), and the first air-impermeable rubber compound comprises 10 to 50 weight % of halogenated butyl rubber and/or halogenated isobutylene-paramethyl styrene copolymer and 90 to 50 weight % of diene rubber in its rubber base, the second air-impermeable rubber compound forms an inner layer (12i) defining the tyre inner surface, and the second air-impermeable rubber compound comprises 60 to 100 weight % of halogenated butyl rubber and/or halogenated isobutylene-paramethyl styrene copolymer and 40 to 0 weight % of diene rubber in its rubber base, a minimum torque of the first air-impermeable rubber compound is at least 1.1 times a minimum torque of the second air-impermeable rubber compound, wherein the minimum torque is measured under a temperature of 170 deg.C, an angularly amplitude of plus/minus 1 degrees, and an oscillation of 100 cycles/minute.

4. A pneumatic tyre according to claim 3, **characterised in that** the thickness of the first air-impermeable rubber compound forming the outer layer (12o) measured form the innermost points of the carcass cords to the inner surface of the outer layer is in a range of from 0.1 to 0.2 mm.

5. A pneumatic tyre according to claim 3 or 4, **characterised in that** the complex elastic modulus E*1 of the first air-impermeable rubber compound is not more than 5.5 MPa, and the complex elastic modulus E*2 of the second air-impermeable rubber compound is not more than 5.0 MPa.

6. A pneumatic tyre according to claim 3 or 4, **characterised in that** the complex elastic modulus E^*1 of the first air-impermeable rubber compound is not more than 5.5 MPa, and the complex elastic modulus E^*2 of the second air-impermeable rubber compound is not more than 5.0 MPa and smaller than the complex elastic modulus E^*1.

7. A pneumatic tyre according to claim 2, **characterised in that** said one kind of air-impermeable rubber compound is a topping rubber for said cords (10) of the carcass ply which covers at least the inside of the carcass ply.

8. A pneumatic tyre according to claim 3, **characterised in that** said first air-impermeable rubber compound is a topping rubber for said cords (10) of the carcass ply which covers at least the inside of the carcass ply.

9. A pneumatic tyre according to claim 7, **characterised in that** the outside of the carcass ply (6) is covered with a topping rubber compound different from said one kind of air-impermeable rubber compound.

10. A pneumatic tyre according to claim 8, **characterised in that** the outside of the carcass ply (6) is covered with a topping rubber compound different from said first air-impermeable rubber compound.

11. A pneumatic tyre according to any of claims 1 to 10, **characterised in that** said carcass ply has a joint covered with a thin rubber patch disposed on the tyre inner surface.

12. A pneumatic tyre according to any of claims 1 to 10, **characterised in that** said carcass ply has a joint exposed on the tyre inner surface.

13. A pneumatic tyre according to any of claims 1 to 10, **characterised in that** said carcass ply has a joint covered with a thin rubber patch disposed on the tyre inner surface, and a mould release agent is applied to the tyre inner surface.

14. A pneumatic tyre according to any of claims 1 to 10, **characterised in that** said carcass ply has a joint exposed on the tyre inner surface, and a mould release agent is not applied to the tyre inner surface.

Fig.1

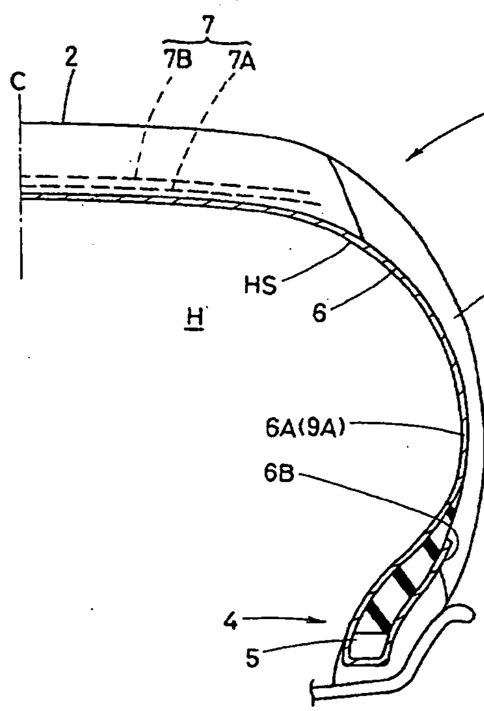

Fig.2A

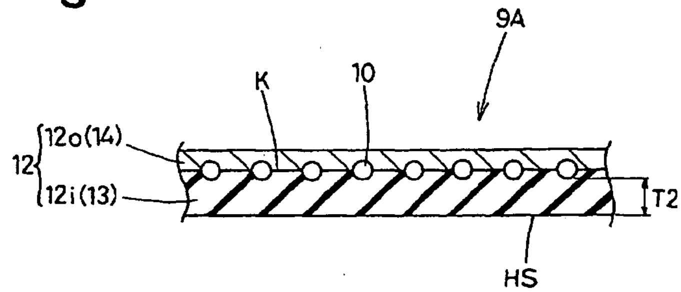

Fig.2B

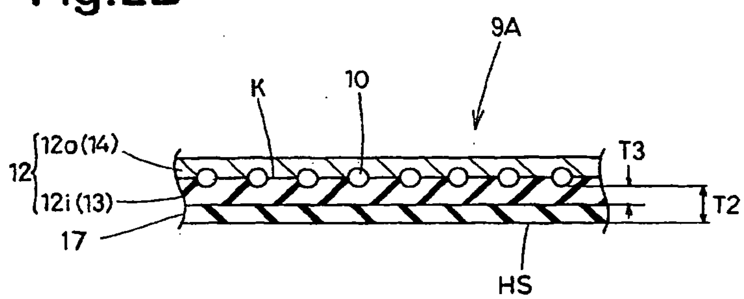

Fig.3

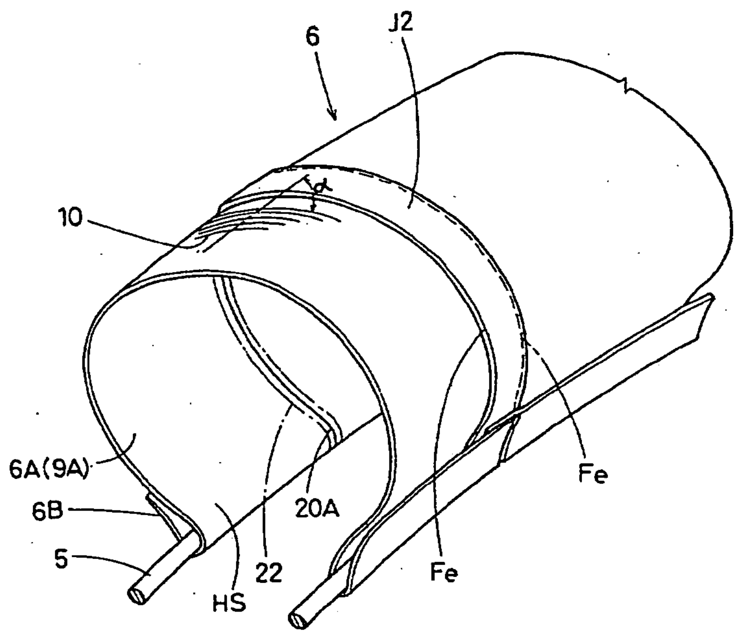

Fig.4

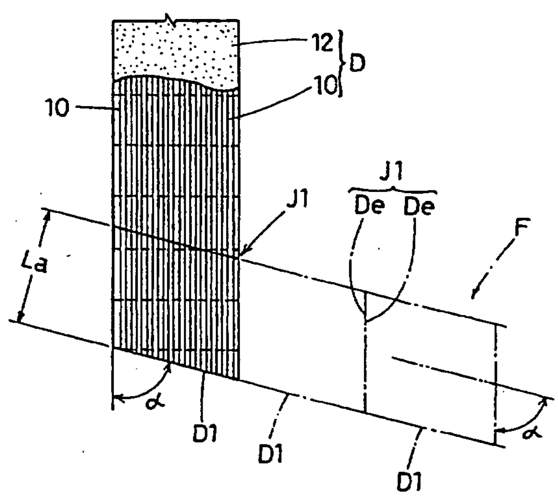

Fig.5A

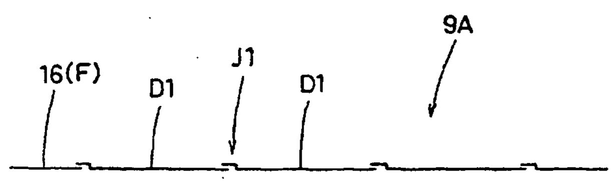

Fig.5B

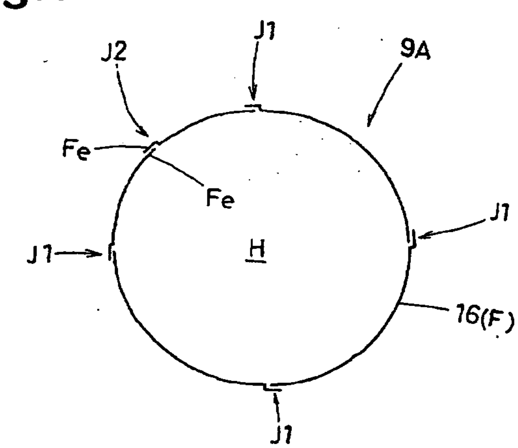

Fig.5C

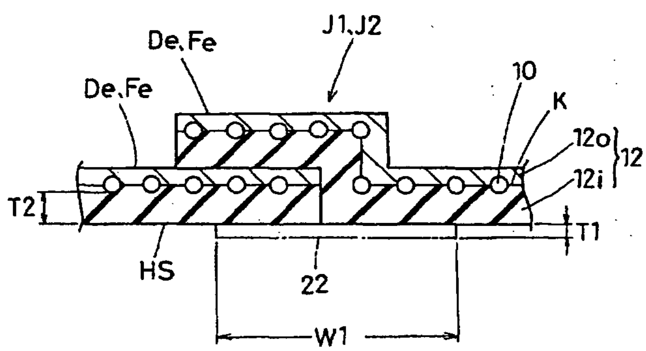

Fig.6A

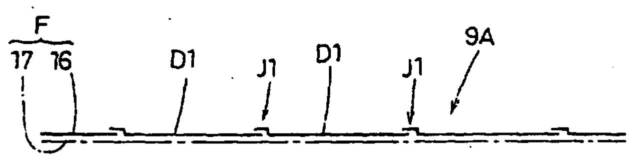

Fig.6B

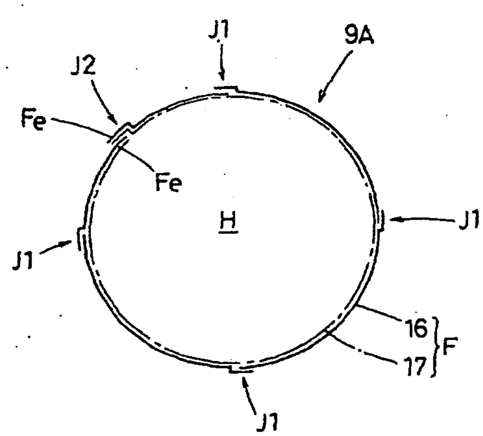

Fig.6C

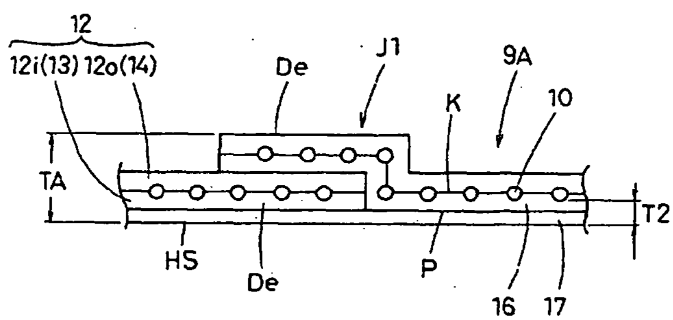
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Fig.6D

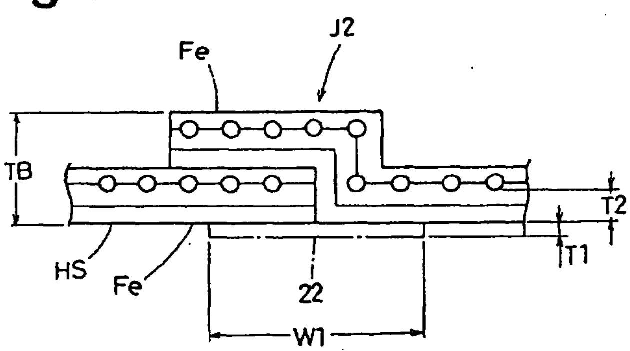
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Fig.7

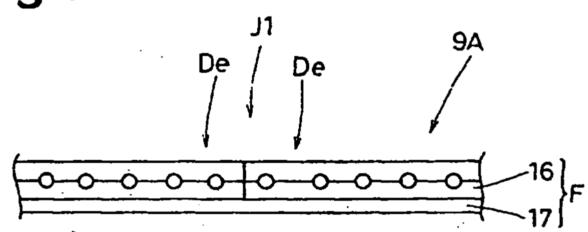
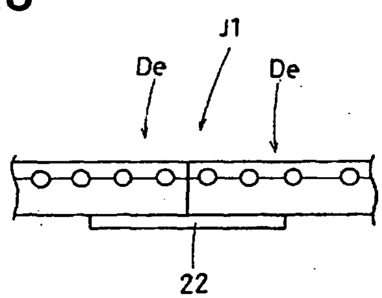


Fig.8



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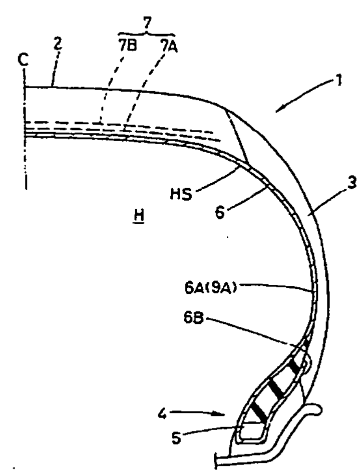
(54) **Pneumatic tyre**

(57) A pneumatic tyre comprising a carcass (6) comprising a ply (9) of cords (10) defining the innermost reinforcing cord layer extending between bead portions (4), and an airtight layer disposed inside the cords (10) of the carcass ply along the inner surface of the tyre, covering the substantially entire inner surface of the tyre, wherein the airtight layer is made of air-impermeable rubber including at least 10 weight % of halogenated butyl rubber and/or halogenated isobutylene-paramethyl styrene copolymer in its rubber base, and a thickness (T2) of the airtight layer measured from the inner surface of the tyre to the cords of the carcass ply is in a range of from 0.2 to 0.7 mm.

Fig.1



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EUROPEAN SEARCH REPORT

Application Number
EP 01 30 8434

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
Y	PATENT ABSTRACTS OF JAPAN vol. 1998, no. 12, 31 October 1998 (1998-10-31) & JP 10 193926 A (YOKOHAMA RUBBER CO LTD:THE), 28 July 1998 (1998-07-28) * the whole document *	1-13	B60C9/02 B60C5/14 B60C1/00 B60C5/12
Y	PATENT ABSTRACTS OF JAPAN vol. 1998, no. 12, 31 October 1998 (1998-10-31) & JP 10 193910 A (YOKOHAMA RUBBER CO LTD:THE), 28 July 1998 (1998-07-28) * the whole document *	1-13	
P,A	US 6 148 889 A (SUZUKI KAZUYA ET AL) 21 November 2000 (2000-11-21) * abstract; figure 2 *	1	

TECHNICAL FIELDS SEARCHED (Int.Cl.7)

B60C

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	18 February 2003	Boone, J

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18-02-2003

Patent document cited in search report		Publication date	Patent family member(s)			Publication date
JP 10193926	A	28-07-1998	NONE			
JP 10193910	A	28-07-1998	NONE			
US 6148889	A	21-11-2000	JP	2962658	B2	12-10-1999
			JP	8113007	A	07-05-1996
			US	5971049	A	26-10-1999
			DE	69505478	D1	26-11-1998
			DE	69505478	T2	11-03-1999
			EP	0705717	A2	10-04-1996
			US	5688343	A	18-11-1997

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